FORM PTO-1390 (Modified) (REV 10-95) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	8733.20069
	U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR **09/446330**

INTERNATIONAL APPLICATION NO. **PCT/BY98/00004**	INTERNATIONAL FILING DATE **21 APRIL 1998**	PRIORITY DATE CLAIMED

TITLE OF INVENTION

   LIQUID CRYSTAL DISPLAY WITH WIDE VIEWING ANGLE AND METHOD FOR MAKING IT

APPLICANT(S) FOR DO/EO/US

   KONOVALOV, Victor A.; MINKO, Anatoly A.; MURAVSKY, Anatoly A., and YAKOVENKO, Sergey E.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.

2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.

3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).

4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. ☐ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))

    a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).

    b. ☒ has been transmitted by the International Bureau.

    c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).

6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).

7. ☒ A copy of the International Search Report (PCT/ISA/210).

8. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C 371 (c)(3))

    a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).

    b. ☒ have been transmitted by the International Bureau.

    c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.

    d. ☐ have not been made and will not be made.

9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).

10. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).

11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).

12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 18 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.

15. ☐ A **FIRST** preliminary amendment.

    A **SECOND** or **SUBSEQUENT** preliminary amendment.

16. ☐ A substitute specification.

17. ☐ A change of power of attorney and/or address letter.

18. ☐ Certificate of Mailing by Express Mail

19. ☒ Other items or information:

    White Advance Serial Number Postcard
    Copy of PCT/BY98/00004 published as WO 98/57222 (including International Search Report)

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/446330	PCT/BY98/00004	8733.20069

20. The following fees are submitted:		CALCULATIONS PTO USE ONLY

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

☒ Search Report has been prepared by the EPO or JPO	$840.00	
☐ International preliminary examination fee paid to USTPO (37 CFR 1.482)	$670.00	
☐ No international preliminary examination fee paid to USTPO (37 CFR 1.482) but international search fee paid to USTPO (37 CFR 1.445(a)(2))	$760.00	
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USTPO	$970.00	
☐ International preliminary examination fee paid to USTPO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)	$96.00	

ENTER APPROPRIATE BASIC FEE AMOUNT =	$840.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☒ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	$130.00	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	16 - 20 =	0	x $18.00	$0.00	
Independent claims	4 - 3 =	1	x $78.00	$78.00	
Multiple Dependent Claims **(check if applicable)**.			☐	$0.00	

TOTAL OF ABOVE CALCULATIONS =	$1,048.00	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable)**. ☐	$0.00	
SUBTOTAL =	$1,048.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +	$0.00	
TOTAL NATIONAL FEE =	$1,048.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable)**. ☐	$0.00	
TOTAL FEES ENCLOSED =	$1,048.00	

|	Amount to be: refunded	$
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☒ A check in the amount of **$1,048.00** to cover the above fees is enclosed.

☐ Please charge my Deposit Account No. in the amount of to cover the above fees.
   A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **50-0911** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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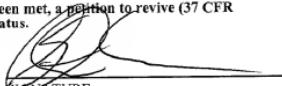
SIGNATURE

KELBER, Steven B.
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30,073
REGISTRATION NUMBER

21 DECEMBER 1999
DATE

Docket No.   8733.20069

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE APPLICATION OF: Victor A. KONOVALOV, et al.   GAU: TBA

SERIAL NO: 09/446,330   EXAMINER: TBA

FILING DATE: December 21, 1999

FOR: LIQUID CRYSTAL DISPLAY WITH WIDE VIEWING ANGLE AND
METHOD FOR MAKING IT

PRELIMINARY AMENDMENT

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:

      Prior to examination, please amend the above-identified application as follows:

IN THE CLAIMS:

      Please cancel claims 3, 7 and 15, without prejudice, and add new claims 17-70 as follows.

- -17.   A liquid crystal display device comprising:

      first and second substrates;

      a liquid crystal layer having a first dielectric constant between the first and second

substrates; and

      a material having a second dielectric constant over the first substrate, the material

extending into the liquid crystal layer.

18.   A liquid crystal display device according to claim17, further comprising a transparent

conductive layer between the first substrate and the material.

19. A liquid crystal display device according to claim17, further comprising an alignment layer over the first substrate and the material.

20. A liquid crystal display device according to claim 19, wherein the alignment layer includes a homeotropic alignment layer.

21. A liquid crystal display device according to claim17, wherein the first and second dielectric constants are different.

22. A liquid crystal display device according to claim17, wherein the liquid crystal layer includes a negative dielectric anisotropy liquid crystal.

23. A liquid crystal display device according to claim17, wherein the liquid crystal display device is a multi-domain liquid crystal display device.

24. A liquid crystal display device comprising:

first and second substrates;

a liquid crystal layer between the first and second substrates; and

a transparent conductive layer over the first substrate, the transparent conductive layer having a first portion and a second portion, the second portion being spaced from the first portion.

25. A liquid crystal display device according to claim 24, wherein the first portion and the second portion each correspond to first and second electric fields.

26. A liquid crystal display device according to claim 25, wherein the first and second electric fields have opposite polarities.

27. A liquid crystal display device according to claim 24, further comprising an alignment layer over the transparent conductive layer.

28. A liquid crystal display device according to claim 27, wherein the alignment layer includes a homeotropic alignment layer.

29.   A liquid crystal display device according to claim 24, wherein the liquid crystal layer includes a negative dielectric anisotropy liquid crystal.

30.   A liquid crystal display device according to claim 24, wherein the liquid crystal display device is a multi-domain liquid crystal display device.

31.   A liquid crystal display device comprising:

first and second substrates;

a liquid crystal layer having a first dielectric constant between the first and second substrates;

a transparent conductive layer over the first substrate, the transparent conductive layer has first and second end portions;

a material having a second dielectric constant over the transparent conductive layer, the material extending into the liquid crystal layer, the material separating the liquid crystal layer into first and second regions, the first and second regions corresponding to first and second electric fields, the material distorting the first and second electric fields.

32.   A liquid crystal display device according to claim 31, wherein the end portions of the transparent conductive layer distorts the first and second electric fields.

33.   A liquid crystal display device according to claim 31, further comprising an alignment layer over the first substrate and the material.

34.   A liquid crystal display device according to claim 33, wherein the alignment layer includes a homeotropic alignment layer.

35.   A liquid crystal display device according to claim 31, wherein the first and second dielectric constants are different.

36.   A liquid crystal display device according to claim 31, wherein the liquid crystal layer includes a negative dielectric anisotropy liquid crystal.

-3-

37.   A liquid crystal display device according to claim 31, wherein the liquid crystal display device is a multi-domain liquid crystal display device.

38.   A liquid crystal display device comprising:

first and second substrates;

a liquid crystal layer between the first and second substrates; and

a transparent conductive layer over the first substrate, the transparent conductive layer having a first portion and a second portion, the second portion being spaced from the first portion, the first portion and the second portion each correspond to first and second electric fields, wherein

each of the first and the second portions of the transparent conductive layer has an end portion, the end portion distorting a corresponding electric field.

39.   A liquid crystal display device according to claim 38, wherein the first and second electric fields have opposite polarities.

40.   A liquid crystal display device according to claim 38, further comprising an alignment layer over the transparent conductive layer.

41.   A liquid crystal display device according to claim 40, wherein the alignment layer includes a homeotropic alignment layer.

42.   A liquid crystal display device according to claim 38, wherein the liquid crystal layer includes a negative dielectric anisotropy liquid crystal.

43.   A liquid crystal display device according to claim 38, wherein the liquid crystal display device is a multi-domain liquid crystal display device.

44. A method of making a liquid crystal display device having first and second substrates comprising:

　　　forming a liquid crystal layer having a first dielectric constant between the first and second substrates; and

　　　forming a material having a second dielectric constant over the first substrate, the material extending into the liquid crystal layer.

45. A method according to claim 44, further comprising a transparent conductive layer between the first substrate and the material.

46. A method according to claim 44, further comprising an alignment layer over the first substrate and the material.

47. A method according to claim 46, wherein the alignment layer includes a homeotropic alignment layer.

48. A method according to claim 44, wherein the first and second dielectric constants are different.

49. A method according to claim 44, wherein the liquid crystal layer includes a negative dielectric anisotropy liquid crystal.

50. A method according to claim 44, wherein the liquid crystal display device is a multi-domain liquid crystal display device.

51. A method of making a liquid crystal display device having first and second substrates comprising:

　　　forming a liquid crystal layer between the first and second substrates; and

　　　forming a transparent conductive layer over the first substrate, the transparent conductive layer having a first portion and a second portion, the second portion being spaced from the first portion.

52.   A method according to claim 51, wherein the first portion and the second portion each correspond to first and second electric fields.

53.   A method according to claim 52, wherein the first and second electric fields have opposite polarities.

54.   A method according to claim 51, further comprising an alignment layer over the transparent conductive layer.

55.   A method according to claim 54, wherein the alignment layer includes a homeotropic alignment layer.

56.   A method according to claim 51, wherein the liquid crystal layer includes a negative dielectric anisotropy liquid crystal.

57.   A method according to claim 51, wherein the liquid crystal display device is a multi-domain liquid crystal display device.

58.   A method of making a liquid crystal display device having first and second substrates comprising:

        forming a liquid crystal layer having a first dielectric constant between the first and second substrates;

        forming a transparent conductive layer over the first substrate, the transparent conductive layer has first and second end portions;

        forming a material having a second dielectric constant over the transparent conductive layer, the material extending into the liquid crystal layer, the material separating the liquid crystal layer into first and second regions, the first and second regions corresponding to first and second electric fields, the material distorting the first and second electric fields.

59.   A method according to claim 58, wherein the end portions of the transparent conductive layer distorts the first and second electric fields.

60. A method according to claim 58, further comprising an alignment layer over the first substrate and the material.

61. A method according to claim 60, wherein the alignment layer includes a homeotropic alignment layer.

62. A method according to claim 58, wherein the first and second dielectric constants are different.

63. A method according to claim 58, wherein the liquid crystal layer includes a negative dielectric anisotropy liquid crystal.

64. A method according to claim 58, wherein the liquid crystal display device is a multi-domain liquid crystal display device.

65. A method of making a liquid crystal display device having first and second substrates comprising:

forming a liquid crystal layer between the first and second substrates; and

forming a transparent conductive layer over the first substrate, the transparent conductive layer having a first portion and a second portion, the second portion being spaced from the first portion, the first portion and the second portion each correspond to first and second electric fields, wherein

each of the first and the second portions of the transparent conductive layer has an end portion, the end portion distorting a corresponding electric field.

66. A method according to claim 65, wherein the first and second electric fields have opposite polarities.

67. A method according to claim 65, further comprising an alignment layer over the transparent conductive layer.

-7-

68.   A method according to claim 67, wherein the alignment layer includes a homeotropic alignment layer.

69.   A method according to claim 65, wherein the liquid crystal layer includes a negative dielectric anisotropy liquid crystal.

70.   A method according to claim 65, wherein the liquid crystal display device is a multi-domain liquid crystal display device.- -

REMARKS

By this Preliminary Amendment, Applicants have added new Claims 17-70. Accordingly, Claims 1, 2, 4-6, 8-14 and 16-70 are pending in this application. Examination of the claims is respectfully requested.

Applicant's undersigned attorney may be reached in our Washington, D.C. office at 202-624-1250. All correspondence should be directed to the address listed below.

Respectfully submitted,

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THE LIQUID CRYSTAL DISPLAY WITH WIDE VIEWING ANGLE AND METHOD FOR MAKING IT

5

Field of the Invention

The present invention relates generally to the field of electronics and may be used for making displays and, in particular, liquid crystal information displays, panels, cells e.t.c.

10

Prior Art

The methods for making liquid crystal displays are known [I.C.Khoo, S.T.Wu, Optics and nonlinear optics of liquid crystals (World Scientific, London) 1993, 390p.- 1]. Basically, they

15 consist of depositing on two flat substrates electrical conductive and planar alignment layers and filling the space between the substrates with liquid crystal with positive dielectric anisotropy. Orientation of the liquid crystal is gradually twisted to 90° in the plane of the substrates. Polarization of the light passing such display is similarly twisted and in crossed polaroids it transmits light. By applying electric field to the electrodes optical axis of the liquid

20 crystal is reoriented perpendicular to the electrodes and such device does not rotate more the light polarization. Due to this in crossed polaroids such device does not transmit light. A set of bright and dark elements makes any picture, half-tone picture as well, because the degree of light transmission gradually depends on the value of the applied voltage.

There are also known liquid crystal devices and methods for making them, as that one

25 described in [S.T.Wu, C.S.Wu, SID Digest 27, 763 (1996) - 2]. According to it a chiral liquid crystal with negative dielectric anisotropy is placed between the substrates supplied with electrically conductive electrodes and homeotropically aligning coatings. In crossed polaroids such device does not transmit the light. Under applied electric field optical axis of the liquid crystal tends to orient perpendicular to the electric field in the whole space between the

30 substrates. Given the chirality of the liquid crystal is such that the pitch of its spontaneous twist equals for times the liquid crystal thickness, then under the electric field the liquid crystal spontaneously twists to 90°. In the vicinity of the substrates orientation of the liquid crystal is

2

which is caused either by the anisotropy of the design, or by the residual anisotropy of the homeotropically aligning coating. With polaroids oriented parallel to the liquid crystal optical axis close to the adjacent substrate (and consequently perpendicularly to each other) one can provide such conditions, when polarization of the light follows the

5   liquid crystal orientation. With electric field applied, such device transmits light, the amount of which may be gradually reduced by decreasing the applied voltage.

The drawback of this device, as well as of that one described in [1], is strong dependence of its transmission on the incidence angle of ight. As a consequence, at some observation angles strong decrease of the contrast and even its inversion are observed.

10   According to the technical reference, which is the closest to the proposed one from the point of view of its technical content, to reduce this undesirable phenomenon the known method [1] is modified so, that the area of each pixel consists of domains with various possible orientation of the liquid crystal in the plane of the substrates [M.Schadt, Proc.SID'97, 24.1 (1997).- 3]. This is achieved by depositing photocured polymer coating

15   with the subsequent irradiation of different domains of a pixel with ultraviolet light of various polarization (applying multiple photolithography with precise alignment). Liquid crystal alignment at the surface of such coating is determined by the polarization of the polymerizing radiation and therefore is different in different domains of a pixel. In such a case, light transmission of each pixel is the sum of the transmissions of domains

20   with different orientation of the liquid crystal and therefore does not depend on the azimuthal viewing angle. This also eliminates inversion of the intermediate transmission levels. Complexity and high cost (due to multiple photolithography) are the drawbacks of this Technical reference.

Another device is commonly used. [N.Yamagishi, H.Watanabe, K.Yokoyama, 'Japan

25   Display 89', 316 (1989) - 4], according to which the viewing angle of liquid crystal devices is improved by using special retardation films between the liquid crystal layer and polaroids. Unfortunately, this increases the cost of such devices.

Summary of the Invention

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The object of invention is to simplify the method for making liquid crystal devices by reducing the number of technological operations and consequently to reduce the cost of liquid crystal display without sacrificing the quality (wide viewing angle).

To achieve this, the electric field applied to the liquid crystal in such display has the non-uniform component parallel to the plane of the substrates, which leads to the non-uniform reorientation of the aforementioned liquid crystal in the space between the aforementioned electrodes within the pixel area and hence improves optical properties of

5 this display in various directions of observation.

According to the method electrically conducting and homeotropically aligning layers are deposited on the surfaces of two flat substrates, faced to each other and fill the space between these substrates with the liquid crystal possessing negative dielectric anisotropy. Without electric field the liquid crystal molecules are orthogonal to the substrates and

10 this device does not transmit light in crossed polaroids. Under electric field liquid crystal reorients perpendicular to the electric field not uniformly across the pixel area, but according to the direction of the in-plane component of the electric field. In this way the domains with different (including opposite) orientation of liquid crystal are formed. At various viewing angles different domains have different transmission levels and

15 transmittance of the whole pixel equals to some averaged value. Due to this the phenomenon of inversion of levels with intermediate transmission is reduced for all observation angles, as this takes place in the known device [3].

One can also use non-chiral as well as chiral liquid crystal. In the first case, light transmittance of the liquid crystal between crossed polaroids planarly aligned by the

20 electric field is caused only by birefringence of the liquid crystal. To maximize transmittance under electric field one should align polaroids at 45° to the optical axis of the liquid crystal and the doubled product of the liquid crystal thickness by its birefringence should be equal to the odd number of the light wavelengths. There are four possible variants of such orientation of the liquid crystal and the case, when all four

25 kinds of these domains occupy similar area, meets the requirements of this invention best of all. Due to decrease of the light transmittance with the deviations of the liquid crystal from optimal orientation, the maximal transmittance value can be achieved when under electric field the liquid crystal forms domains with uniform orientation of the liquid crystal within the domain area, the aforementioned orientation having 45° angle with the

30 polaroids direction.

Transmittance of the twisted nematic liquid crystal structure between crossed polaroids depends on the orientation of the liquid crystal axis in their vicinity relative to the polaroids axes. In the case they coincide and the product of the liquid crystal thickness by its birefringence exceeds the light wavelength, polarization of the transmitted light

                                         4

follows the liquid crystal twist. This ensures maximal transmittance of the known device fabricated according to the known method [3] under electric field provided this electric field exceeds the threshold value for the particular liquid crystal. In the proposed device fabricated according to the proposed method the liquid crystal can have various

5   orientation of its optical axis under electric field and to achieve maximal transmittance one should have the product of the liquid crystal thickness by its birefringence equal to the integer number of the light wavelengths. In this case polarization of the light passing the liquid crystal is also twisted to 90° and practically 100% of light are transmitted by the second polaroid.

10 The aforementioned requirements to the liquid crystal thickness are valid when both substrates and both electrodes are transparent and the device according the invention is used to display image with the transmitted light. In the case the device according the invention is used in reflection mode, one of the aforementioned substrates and the electrode deposited on it are made non-transparent (reflective) and for displaying image

15 only one polaroid is used. In this case the preferred orientation (twisted, or not; configuration of domains) and thickness of the liquid crystal in various areas may be calculated with the methods [D.W.Berreman, Appl.Phys.Letters, 35, 12 (1974) - 5] known for homogeneously aligned nematic structures. To increase the contrast one may combine the proposed method with the known one [4] in which retardation films are

20 used. According to the proposed method one may introduce dichroic dyes in the liquid crystal filling the gap between the substrates and then such device may display images without polaroids but due to the light absorption by the dye molecules. The aforementioned dye may have dichroic ratio larger than one or smaller and the aforementioned liquid crystal may be both chiral or non-chiral.

25

There are various methods to create in-plane with the electrodes component of the electric field, when it is applied to the liquid crystal. For example, this can be achieved by special patterning of the electrodes surrounding the liquid crystal, or by displacing dielectric particles by deposing special dielectric films being reliefed as on the liquid

30 crystal side so on the substrate side, said particles divide the pixel into parts with different orientation of the electric field. Even the pixel edges themselves cause the non-uniformity of the electric field in the vicinity of the pixel boarders and therefore they also may be used for this purpose. Essential is to create such conditions that electric field

applied to the liquid crystal has parallel to the substrates components, these components have different direction i.e. different azimuth angle in different pixel areas.

Brief Description of Drawings

5   Fig.1 displays the cross-section of the liquid crystal display according to [2] in the state without (a) and with (b) the electric field applied to the liquid crystal. The display consists of the glass substrates 1 with the column 2 and row 3 electrodes deposited on them and homeotropically aligning coating 4. Liquid crystal 5, the molecules of which

10   are shown as cylinders, is placed between the glass substrates 1.

In Fig.2 the top view and the cross-section of the liquid crystal device according the invention is shown in the state without (a) and with (b) the electric field applied to the liquid crystal. Liquid crystal 5, the molecules of which are shown as cylinders, is placed between the glass substrates 1 with the column 2 and row 3 electrodes deposited on them

15   and homeotropically aligning coating 4. Different columns of cylinders correspond to the domains with different orientation of the liquid crystal (rotated to about 150 degrees in the plane of the substrates 1). The arrows show orientation of the liquid crystal in the central plane of the device.

In Fig.3 the top view and the cross-section of the electrodes pattern are shown

20   schematically for the segment-type (a) and the matrix-type (b) liquid crystal devices. The arrows show the force lines of the electric field. The component of the electric field parallel to the substrates is shown at the edges of the electrodes.

Fig.4 schematically shows the top view and the cross-section of the electrodes. The arrows show the force lines of the electric field. The component of the electric field

25   parallel to the substrates is shown arising at the slits in the electrodes.

Fig.5 schematically shows the top view and the cross-section of the electrodes. The arrows show the force lines of the electric field. The component of the electric field parallel to the substrates is shown arising when different polarity is applied to the electrodes comprising the same pixel.

30   Fig.6 schematically shows the top view and the cross-section of the electrodes. The arrows show the force lines of the electric field. The component of the electric field parallel to the substrates is shown arising around the additional dielectric particle with the dielectric permittivity different from that of the liquid crystal.

In Fig.7 the light transmittance of the device made according to the known method [2] is displayed as a function of azimuth angle for the polar viewing angle equal 30 (a) and 50 (b) degrees. Different curves correspond to different levels of the applied electric field (its amplitude in Volts is shown in the brackets).

5   In Fig.8 the light transmittance of the device according the invention is displayed as a function of azimuth angle for the polar viewing angle equal 30 (a) and 50 (b) degrees. Different curves correspond to different levels of the applied electric field (its amplitude in Volts is shown in the brackets).

10   Detailed Description of the Invention

According to the proposed method we made liquid crystal display. For this, at the glass substrates 1 0.5 - 2 mm thick and with linear dimensions from 1 cm to several decimeters we deposited by vacuum sputtering column 2 and row 3 transparent electrodes 70-150 15   nm thick, made of indium-tin oxide with the surface resistivity 20-2000 Ohm/□. The electrodes were patterned photolithographically. At the same surfaces homeotropically aligning coating 4, such as lecithin, with the thickness 20-80 nm was spinned and baked. The substrates were overlaid with the aligning layers faced to each other, sealed with the glue based on epoxy resin and the gap was filled with the liquid crystal with negative 20   dielectric anisotropy. The conditions for appearing the component of the electric field parallel to the substrates, when this electric field is applied through the electrodes 2 and 3 to the liquid crystal, were created by one of the methods described below.

Conditions for appearing the parallel to the substrates component of the electric field can be created in various ways. The opposite electrodes in the segment-type liquid crystal 25   device can be made of different dimensions, as it is shown, for example, in Fig.3. Then, at the edges of the segment, electric field is orthogonal to the substrates not in the entire space between the electrodes (Fig.3a). In the matrix-type liquid crystal device (Fig.3b) electric field inevitably has the component parallel to the substrates and in the case the width of the electrodes 2 and/or 3 is comparable (not more than 3-5 time exceeds) the 30   thickness of the liquid crystal layer, this component is sufficient for dividing the pixel into even parts with different orientation of the liquid crystal. In the cases, when the pixels should be of larger dimensions (should exceed the liquid crystal thickness many times) big number of domains with the electric field substantially non-orthogonal to the substrates can be obtained by dividing the electrodes into the parts, as it is shown in

Fig.4. Even stronger horizontal component of the electric field can be obtained if even and odd parts of the electrode are connected to the electric field sources of the opposite polarity, as it is shown in Fig.5. Alternatively, big number of domains with the electric field substantially non-orthogonal to the substrates can be obtained by displacing

5   between the electrodes at the opposite substrates a big number of particles with the dielectric permittivity essentially different from that of the liquid crystal (Fig.6). It can be realized by deposing special dielectric films being releafed as on liquid crystal side so on the substrate side.

10   The device according the invention operates as follows. In the state without the electric field the aligning coating 4 aligns the liquid crystal molecules perpendicular to the substrates 1. In this state the liquid crystal does not influence the polarization of the light passing it and in the crossed polaroids transmittance of the liquid crystal device equals zero. When electric field exceeding the threshold for the particular liquid crystal is

15   applied to the transparent electrodes 2 and 3, the liquid crystal molecules tend to reorient perpendicular to the field. The liquid crystal begins to change polarization of the light passing it and transmittance of the liquid crystal device becomes different from zero. Existence of the component of the electric field which is parallel to the substrates and non-uniformly oriented within the pixel area makes the molecules to decline from the

20   normal to the substrates 1 in different directions (Fig.2) in difference to what happens in the known device (Fig.1). At various viewing angles different domains have different transmittance and the transmittance of the whole pixel equals to some averaged value. Due to this, opposite to the transmittance of the device made without creating conditions for non-uniform reorientation of the liquid crystal under electric field (Fig.7), inversion

25   of the transmittance levels of the liquid crystal display is reduced for all viewing angles (Fig.8).

Tests of the proposed method and the display made by it have evidenced smaller number of operations required to make a display in comparison to the nearest Prior Art method

30   (multiple illuminations by the ultraviolet light with precise alignment of different photomasks are not required). Simultaneously, the display according the invention possesses similarly even angular dependence of the transmittance, high contrast and the absence of the inversion of the transmittance levels at oblique observation angles.

AMENDED CLAIMS
[received by the International Bureau on 12 November 1998 (12.11.98);
original claims 1-18 replaced by new claims 1-16 (3 pages)]

5   1. Liquid crystal display with wide viewing angle comprising nematic liquid
crystal with negative dielectric anisotropy placed between flat parallel substrates
supplied with conductive electrodes and homeotropic aligning layers, orientation of the
said liquid crystal is made non-uniform within the pixel area by means of the parallel to
the said substrates components of the electric field applied to the said electrodes, while
10   the components themselves have various directions
characterized in that
in the space occupied by the said liquid crystal dielectric particles are displaced with
dielectric constant essentially different from dielectric permittivity of the said liquid
crystal.

15   2. Display according to claim 1, characterized in that the said dielectric
particles are made by depositing reliefed dielectric films over the aforementioned
electrodes.

        3. Display according to claim 1, characterized in that the doubled product of
the liquid crystal thickness by its birefringence is made equal to the odd number of the
20   light wavelengths.

        4. Display according to claim 1, characterized in that the said liquid crystal
contains chiral dopant with such concentration that equilibrium pitch of the said liquid
crystal equals four times the liquid crystal thickness and the product of the later by the
liquid crystal birefringence is made equal to the integer number of the light
25   wavelengths.

        5. Display according to claim 1, characterized in that one of the said electrodes
is made reflective.

        6. Liquid crystal display with wide viewing angle comprising nematic liquid
crystal with negative dielectric anisotropy placed between flat parallel substrates
30   supplied with conductive electrodes and homeotropic aligning layers, orientation of the
said liquid crystal is made non-uniform within the pixel area by means of the parallel to
the said substrates components of the electric field applied to the said electrodes, while
the components themselves have various directions

AMENDED SHEET (ARTICLE 19)

characterized in that

odd and even sections of the at least one of the said electrodes been made sectional

5   are connected to the electric field sources of the opposite polarity.

       7. Display according to claim 6, characterized in that the doubled product of the liquid crystal thickness by its birefringence is made equal to the odd number of the light wavelengths.

       8. Display according to claim 6, characterized in that the said liquid crystal 10   contains chiral dopant with such concentration that equilibrium pitch of the said liquid crystal equals four times the liquid crystal thickness and the product of the later by the liquid crystal birefringence is made equal to the integer number of the light wavelengths.

       9. Display according to claim 6, characterized in that one of the said electrodes 15   is made reflective.

       10. Method for making liquid crystal display with wide viewing angle comprising the deposition on conductive electrodes and homeotropic aligning layers of the faced to each other surfaces of the flat parallel substrates and filling the space between them with nematic liquid crystal possessing negative dielectric anisotropy, 20   making the orientation of the said liquid crystal in the space between the said electrodes non-uniform when applying the electric field to the said electrodes with the components of the electric field parallel to the said substrates with various directions characterized in that

the said parallel to the substrates plane component of the electric field is created by 25   displacing in the space occupied by the said liquid crystal dielectric particles with dielectric constant essentially different from dielectric permittivity of the liquid crystal.

       11. Method according to claim 10, characterized in that the said dielectric particles are made by depositing reliefed dielectric films over the aforementioned electrodes.

30   12. Method according to claim 10, characterized in that the doubled product of the liquid crystal thickness by its birefringence is chosen to be equal to the odd number of the light wavelengths.

       13. Method according to claim 10, characterized in that chiral dopant is added to the said liquid crystal with such concentration that equilibrium pitch of the said

liquid crystal equals four times the liquid crystal thickness and the product of the later by the liquid crystal birefringence is made equal to the integer number of the light
5   wavelengths.

14. Method for making liquid crystal display with wide viewing angle comprising the deposition of conductive electrodes and homeotropic aligning layers on the faced to each other surfaces of the flat parallel substrates and filling the space between them with nematic liquid crystal possessing negative dielectric anisotropy,
10   making the orientation of the said liquid crystal in the space between the said electrodes non-uniform when applying the electric field to the said electrodes with the components of the electric field parallel to the said substrates with various directions characterized in that the said parallel to the substrates plane component of the electric field is created by
15   connecting odd and even sections of the said electrodes been made sectional to the electric field sources of the opposite polarity.

15. Method according to claim 14, characterized in that the doubled product of the liquid crystal thickness by its birefringence is chosen to be equal to the odd number of the light wavelengths.

20   16. Method according to claim 14, characterized in that chiral dopant is added to the said liquid crystal with such concentration that equilibrium pitch of the said liquid crystal equals four times the liquid crystal thickness and the product of the later by the liquid crystal birefringence is made equal to the integer number of the light wavelengths.

THE LIQUID CRYSTAL DISPLAY WITH WIDE VIEWING ANGLE AND
METHOD FOR MAKING IT

5   The present invention relates generally to the field of electronics and may be used for making displays and, in particular, liquid crystal information displays, panels, cells e.t.c.

The object of invention is to simplify the method for making liquid crystal devices by reducing the number of technological operations and consequently to reduce the cost

10   of liquid crystal display without sacrificing the quality (wide viewing angle).

To achieve this the electric field applied to the liquid crystal in such display has the non-uniform component parallel to the plane of the substrates, which leads to the non-uniform reorientation of the aforementioned liquid crystal in the space between the

15   aforementioned electrodes within the pixel area and hence improves optical properties of this display in various directions of observation.

OFF   ON

(a)   (b)

Fig.1

Fig.2

(a)   (b)
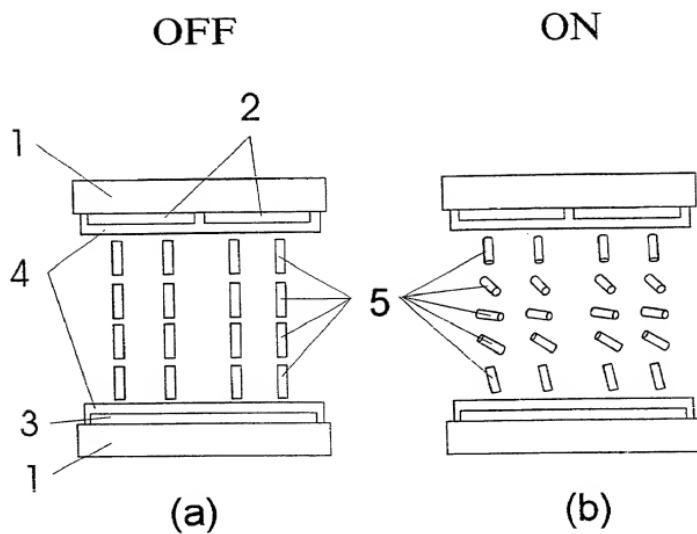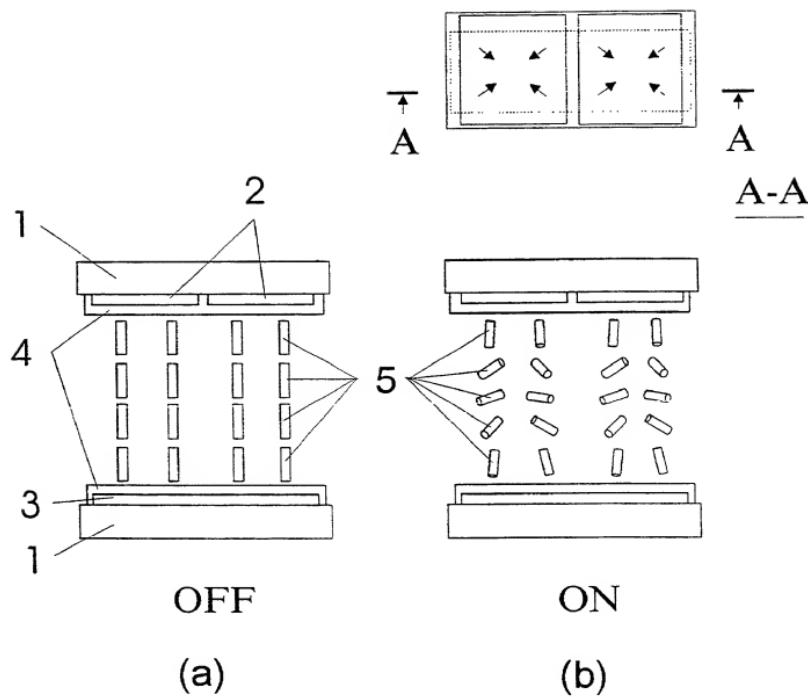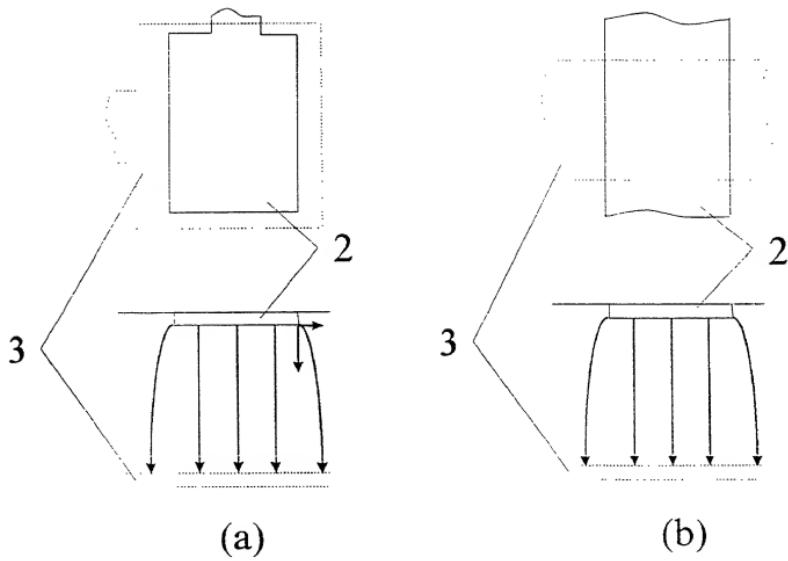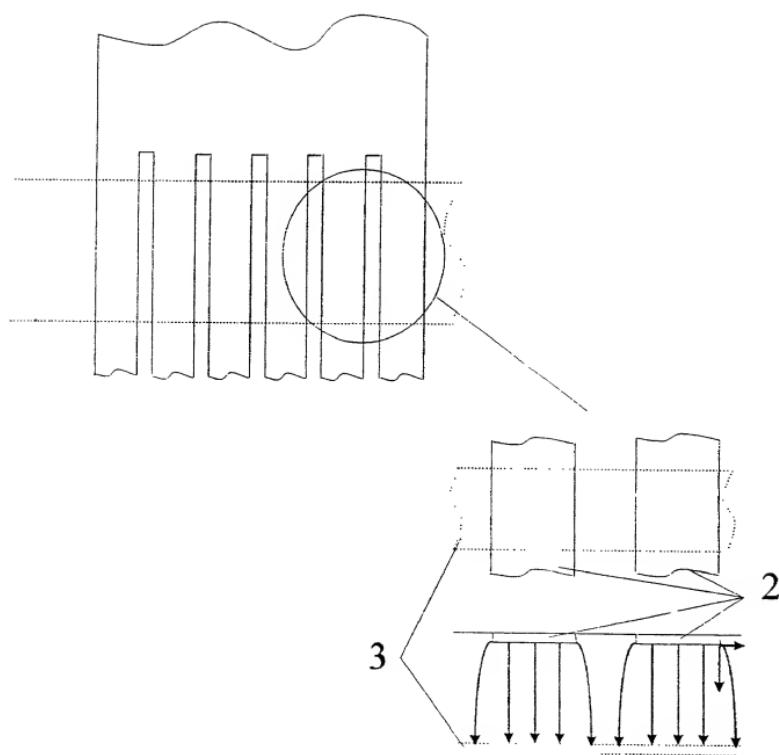
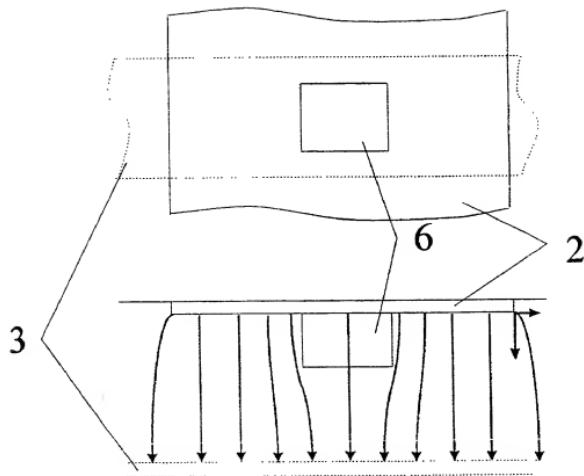Fig.3

Fig.4

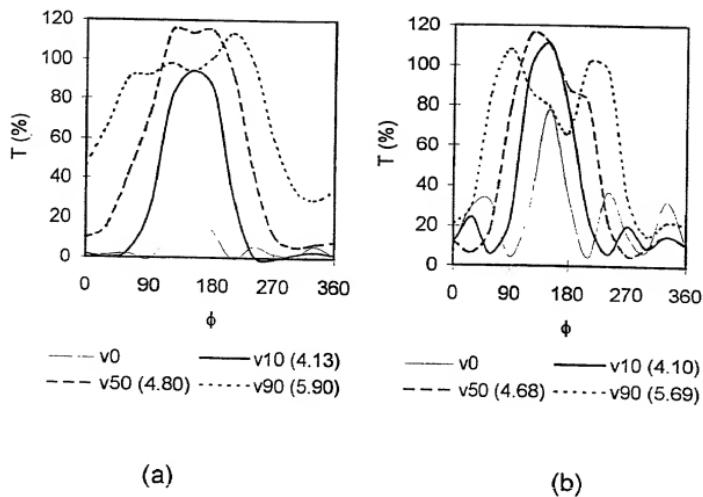Fig.5

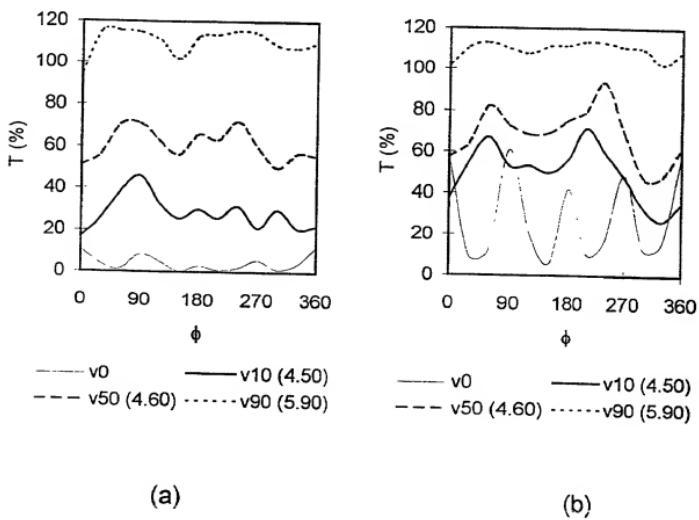Fig.6

Fig.7

(a)   (b)
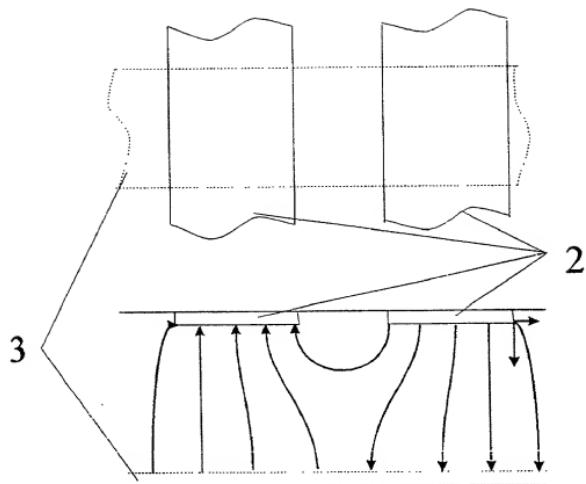
Fig.8

DECLARATION
and POWER OF ATTORNEY

As a below named inventor, I declare that the information given herein is true, that I believe that I am the original, first and sole inventor if only one name is listed at 1 below, or a joint inventor if plural inventors are named below at 1-4, of the invention entitled:

which is described and claimed in: ☐ the attached specification, or ■ the specification in PCT Application No. PCT/BY98/00004 filed April 21, 1998 ☐ as amended on _____ (if applicable),

and for which a patent is sought, and that my residence, post office address and citizenship are as stated below next to my name

I acknowledge my duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed

PRIOR FOREIGN APPLICATION(S)			
COUNTRY	APPLICATION NUMBER	DATE OF FILING Month Day Year	PRIORITY CLAIMED UNDER 35 U.S.C 119
BELARUS	970314	June 10, 1997	YES

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application

_____

(Application Number)   (Filing Date)   (Status)

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I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signature of INVENTOR 1	Signature of INVENTOR 2
DATE: 8.11.1999	DATE: 08.11.1999
Signature of INVENTOR 3	Signature of INVENTOR 4
DATE: 8.11.1999	DATE: 8.11.1999